UNIVERSITI PUTRA MALAYSIA

MEMBRANE FILTRATION APPLICATION IN PRE-TREATMENT OF CRUDE PALM OIL

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MEMBRANE FILTRATION APPLICATION IN PRE-TREATMENT OF CRUDE PALM OIL

By

ONG KEAT KHIM

Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

May 1999

Dedicated to: My family and friends

Healthy and happy life

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science.

MEMBRANE FILTRATION APPLICATION IN PRE-TREATMENT OF CRUDE PALM OIL

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May 1999

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Faculty: Engineering

The pre-treatment of crude palm oil results in loss of oil and a contaminated effluent. The objective of this research is to study the effectiveness of membrane filtration in the pre-treatment of crude palm oil for removal of phospholipids from crude palm oil. Initial investigation with a 25,000 molecular weight cut-off, polysulfone membrane did not yield any significant results. Hence, it was decided to use a PCI module, which was equipped with polyethersulfone membranes having a molecular weight cut-off of 9,000 (type ES209). The membrane process was carried out at 26 bar pressure and a temperature of 63±2°C. The sample, permeate and retentate were analysed for various quality parameters including phosphorus content, carotene content, free fatty acid, colour and volatile matter. The membrane effectively removed phospholipids resulting in a permeate with a phosphorus content of less than 0.3 ppm. The percentage removal of phosphorus was 96.4% and can be considered significant. Lovibond colour was reduced from 27R 50Y to 20R 30Y whereas

the percentage removal of carotene was 17.5%. The removal of colour was considered good but removal of carotene was considered insignificant by the membrane. Free fatty acids and volatile matter were not removed. Typical of membrane operations, the permeate flux decreased with time and must be improved in order to be adopted on an industrial scale. Membrane separation using polyethersulfone type was found to have a good potential in crude palm oil degumming. However, an appropriate method has to be developed to clean the membranes.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains.

PENGGUNAAN MEMBRANE TURASAN DALAM PRA-RAWATAN MINYAK KELAPA SAWIT MENTAH

Oleh

ONG KEAT KHIM

Mei 1999

Pengerusi: **Fakhru'l-Razi Ahmadun, Ph.D**

Fakulti: **Kejuruteraan**

Kaedah pra-rawatan minyak kelapa sawit mentah secara tradisional boleh mengakibatkan kehilangan minyak dan efleun yang tercemar. Objektif kajian ini adalah untuk mengkaji keberkesanan membran turasan dalam pra-rawatan minyak kelapa sawit mentah untuk membuang fosfolipid dari minyak kelapa sawit mentah. Dalam kajian awal yang menggunakan membran polysulfone dengan "molecular weight cut-off" sebanyak 25,000 tidak memberikan keputusan yang signifikan. Oleh itu, satu modul PCI yang dilengkapi dengan membran polyethersufone (jenis ES209) yang mempunyai "molecular weight cut-off" bernilai 9000 digunakan. Proses ini dijalankan pada tekanan 26 bar dan suhu 63±2°C. Sampel, hasil penurasan dan baki penurasan dianalisis untuk dikenalpasti berbagai parameter kualiti termasuk kandungan fosforus, kandungan karoten, asid lemak bebas, warna dan bahan meruap. Daripada hasil penyelidikan ini didapati bahawa membran tersebut dapat membuang fosfolipid dengan

berkesan apabila hasil penurasan mempunyai kandungan fosforus yang kurang daripada 0.3 ppm. Peratus pembuangan fosforus adalah 96.4% dan ia boleh dianggap sebagai signifikan. Warna *Lovibond* berkurangan dari 27R 50Y kepada 20R 30Y dan peratus pembuangan karoten adalah sebanyak 17.5%. Kajian ini menunjukkan bahawa keupayaan pembuangan warna adalah dianggap baik tetapi keupayaan pembuangan karoten adalah dianggap tidak signifikan. Kajian ini juga menunjukkan bahawa asid lemak bebas dan bahan meruap tidak terbuang. Menurut operasi membran yang tipikal, kadar alir penurasan per luas permukaan membran adalah berkurangan dengan masa dan kadar alir ini mesti diperbaiki untuk digunakan dalam skala industri. Membran turasan dengan menggunakan jenis polyethersufone telah didapati mempunyai potensi yang baik dalam penyahgumman minyak kelapa sawit mentah. Walau bagaimana pun, kaedah yang sesuai perlu digunakan untuk mencuci membran.

CHAPTER I

INTRODUCTION

Palm Oil Industry

Normally there are two main products produced, namely crude palm oil and crude palm kernel before further processing and downstream manufacturing activities. The palm oil industry in Malaysia has witnessed a prolific growth in recent years. From being almost non-existent in the 1960s, it has now become the most profitable agricultural commodity (Ibrahim and Ahmad, 1992). In 1996, the total export earning was RM11.51 billion or 6% of Gross Domestic product (GDP). Thus, the palm oil industry plays a significant role in the socio-economic development of Malaysia (Jalani, 1998).

Membrane Technology

There are two routes to refine crude palm oil into refined palm oil; chemical or physical refining (Thiagarajan, 1992). Chemical refining causes oil losses and severe treatments with alkali solution led to chemical damage of the oil. Furthermore, chemical refining also produces a large volume of contaminated wastewater (Rusnani and Affandi, 1995). Hence, physical refining is more common process in Malaysia (Thiagarajan, 1992). One of the refining processing steps is degumming which is used to remove phospholipids and trace metals from crude palm oil. Normally, phosphoric acid is used as a degumming agent (Rusnani and Affandi, 1995). This study reports the effectiveness of membrane filtration application in pre-treatment of crude palm oil.

According to the US Department of Energy, energy savings of 7.2 - 35.3 trillion Btu/year in the US by full implementation of membrane degumming process. In two years, 14.48 million gallons/year of water and 27,670 tonnes/year of solid water will be eliminated with 25% market penetration (Koseoglu, 1996). The use of a membrane technique could reduce oil losses of crude oil (soybean, cottonseed and corn) by 60% due to saponification of neutral oils during chemical refining (Koseoglu and Engelgau, 1990).

The new membrane degumming method is almost a single step operation as shown in Figure 1. This process not only removes all the phospholipids, but also removes the major colour pigments and some of the free fatty acids. Thus bleaching requirements are reduced due to entrapment of some colour pigments by the membrane separation process (Koseoglu, 1996).

Objective of Study

There have been very few innovations in crude palm oil refining in the past two decades in Malaysia. There are a few literature that have been published on the use of membrane technology in edible oil degumming. Therefore, the objective of this research is to study the effectiveness of membrane filtration in pre-treatment of crude palm oil by 25,000 molecular weight cut-off (MWCO) and 9,000 MWCO of membranes oil for the removal of phospholipids. In order to study the effectiveness of membrane technology, analysis of phosphorus content, carotene content, free fatty acids (as palmitic acid), colour and volatile matter will be carried out.

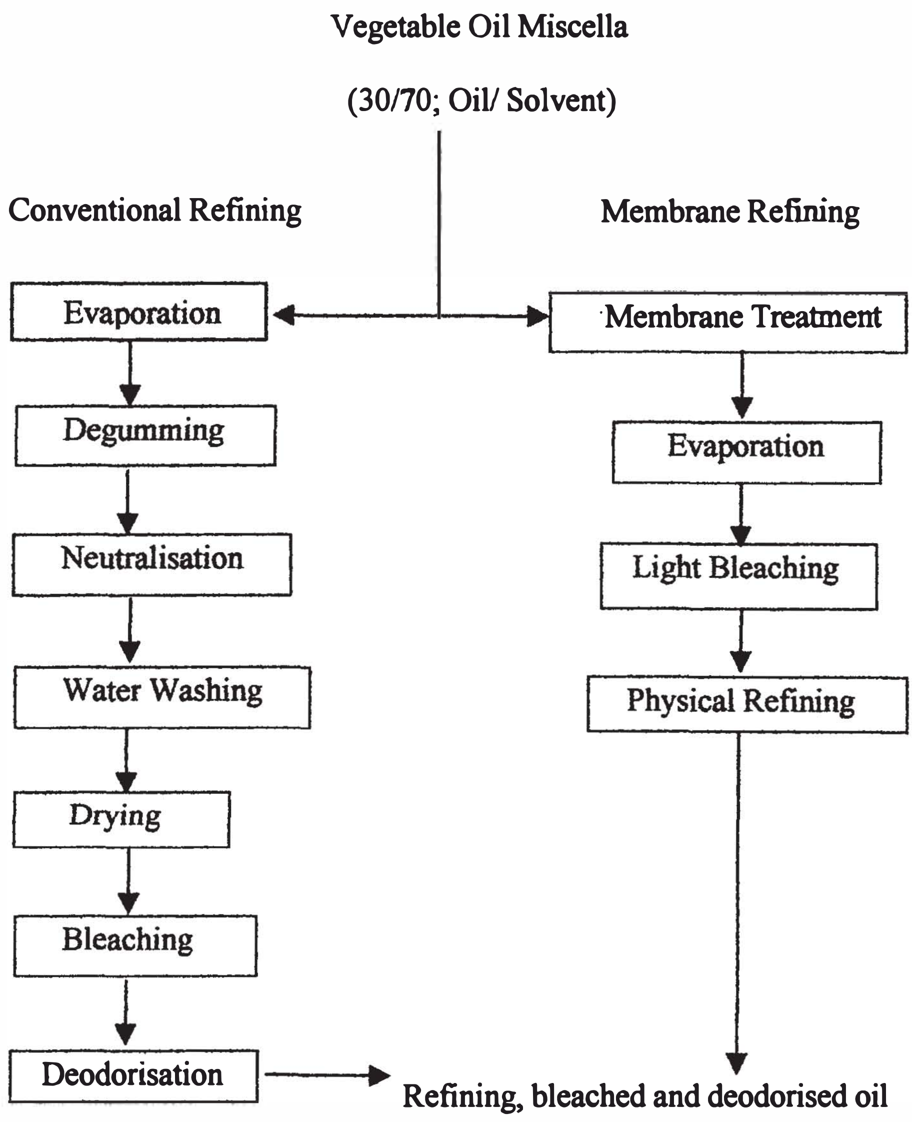

Figure 1: Flow Diagram of Conventional and Membrane Degumming Method
Source: Koseoglu (1996)

CHAPTER II

LITERATURE REVIEW

Palm Oil Statistics

In 1995, Malaysia was the largest exporter of edible oils and fats in the world. Export earnings from palm oil, valued at RM 10.1 billion accounted for 5.5% of total export revenue for the country in that year. The production of palm oil in various forms is shown in Table 1. The global production of palm oil is shown in Table 2 (Ministry of International Trade and Industry, 1996).

Table 1: Production of Crude Palm Oil, Palm Kernel, Palm Kernel Oil and Palm Kernel Cake ('000 mt.)

Year	Crude Palm Oil		Palm Kernel		Palm Kernel Oil		Palm Kernel Cake	
	Total	Growth (%)	Total	Growth (%)	Total	Growth (%)	Total	Growth (%)
1985	4134	11.3	1212	15.9	512	21.0	633	19.4
1986	4542	9.9	1336	10.2	580	13.3	708	11.8
1987	4532	-0.2	1311	-1.9	563	-2.9	726	2.5
1988	5027	11.0	1473	12.4	621	10.3	719	1.0
1989	6056	20.3	1794	21.8	745	20.0	933	29.8
1990	6095	0.6	1845	2.8	827	11.0	1038	11.2
1991	6141	0.8	1785	-3.2	782	-5.4	955	-8.0
1992	6373	3.8	1874	5.0	812	3.8	984	3.0
1993	7403	16.2	2266	20.9	966	19.0	1183	20.2
1994	7221	-2.4	2204	-2.2	978	1.2	1223	3.4
1995	7811	8.2	2396	8.7	1036	5.9	1293	5.7

Source: Ministry of International Trade and Industry (1996)

Table 2: Global Production of Palm Oil

Country	Year			
	1980	1985	1990	1995
Malaysia	2.6	4.1	6.1	7.8
Indonesia	0.7	1.2	2.4	4.2
Africa	0.8	0.7	1.1	1.3
Americas	0.1	0.3	0.5	0.9
Others	0.3	0.5	0.8	1.0
Total	4.6	6.8	10.9	15.2

Source: Ministry of International Trade and Industry (1996)

In the global trade of edible oils and fats, palm oil has increased from 5.7 million mt. in 1985 to 10.5 million mt. in 1995 as shown in Table 3. Palm oil has registered an above average growth from 1985 to 1995 with 35.7% share of the world trade in oils and fats.

Table 3: Comparison of Edible Oils and Fats Traded between 1985 and 1995 (million mt.)

	1985	1995	Export share in % in 1995	Average growth in % p.a.
Palm oil	5.7	10.5	35.7	8.6
Soybean oil	3.6	5.6	19.0	5.7
Sunflower oil	1.9	2.9	9.6	5.1
Tallow	2.6	2.5	8.6	-0.2
Rapeseed oil	1.4	1.9	6.5	4.4
Coconut oil	1.2	1.7	5.8	3.9
Fish oil	1.0	0.8	2.8	-2.0
Palm kernel oil	0.6	0.8	2.6	2.2
Butter	1.1	0.6	1.9	-5.1
Olive oil	0.5	0.5	1.5	-1.2
Others	1.7	1.8	6.0	0.3
Total	21.3	29.6	100.0	3.9

Source: Ministry of International Trade and Industry (1996)

Palm Oil

Crude palm oil (CPO) is extracted from the fibrous mesocarp of the palm fruit (*Elaeis guineensis*) (Tan *et al.*, 1995). Palm oil is semisolid fat with a mean iodine value (IV) of 53.3 and a mean slip point of 36°C. Its saturated: unsaturated fatty acid ratios being ca. 50:40:10 saturated: monoenoate: dienoate (Maclellan, 1983). Triglycerides form a major part in palm oil. In addition, it also contains small amount of partial glycerides, free fatty acids and non-glyceridic material (Tan *et al.*, 1981). About 1% of minor and trace constituents is found in crude palm oil. A diagrammatic presentation of crude palm oil composition is displayed in Figure 2 (Goh *et al.*, 1988).

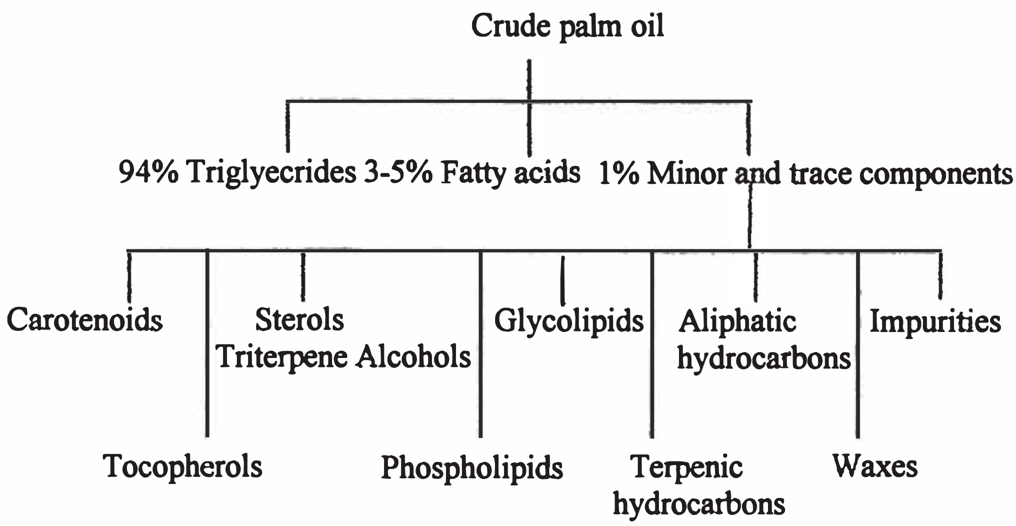

Figure 2: A Diagrammatic of Crude Palm Oil Composition
Source: Goh *et. al.* (1988)

Esterification of glycerol and fatty acids will form triglycerides. Triglycerides govern the properties of palm oil because of their predominance. The influence depends on the types of fatty acids that are esterified with the glycerol molecule. Normally, the fatty acids are straight-chained and have an even number of carbon atoms. They can be differentiated based on the number of carbon atoms and on the presence or absence of one or more double bonds in the carbon chain. Fatty acid with no double bonds is referred to as saturated whereas those with double bonds as unsaturated (Tan *et al.*, 1981).

Carotenoids, tocopherols, sterols, phosphatides, triterpenic and aliphatic alcohols form the minor constituents of palm oil. Though the minor constituents in the palm oil is less than 1%, but they play a significant role in the stability and refinability of the oil. They also increase the nutritive value of the oil (Chong, 1992).

According to Maclellan (1983), the soluble impurities in crude palm oil are referred to as gums or sludge consisting essentially of phospholipids and metal complexes, peroxides and their breakdown products, pigments, free fatty acids and diglycerides. The refined product should have a good stability to oxidation and colour reversal thus enabling the consumer to use the product without further processing. Thus low free fatty acid, low moisture and impurities, good bleachability, minimum oxidation, low mono and digylcerides and high natural antioxidants are the specifications for all refiners. Table 4 shows the characteristics requirements for crude palm oil (SIRIM, 1981). The PORAM standard specifications for neutralised bleached and neutralised (NB), bleached and deodorised (NBD) also refined, bleached and deodorised (RBD) palm oils is shown in Table 5 (Thiagarajan, 1992).

Table 4: Characteristic Requirements for Crude Palm Oil

Characteristics	Requirements for Special quality	Requirements for Standard quality
Free fatty acids, % as palmitic acid, maximum	2.5	5.0
Moisture content, %, maximum	0.20	0.20
Impurities, %, maximum	0.05	0.05
Peroxide value, meq/kg, maximum	3	-
Anisidine value, maximum	4	-

Source: SIRIM (1981)

Table 5: PORAM Standard Specifications for Refined Palm Oils and Factions

	NB Palm oil	RBD/NBD Palm oil
Free fatty acid (% as palmitic)	0.25 max.	0.1 max.
Moisture and Impurities (%)	0.1 max.	0.1 max.
Iodine Value (Wijis)	50-55	50-55
Melting point (°C-AOCS Cc 3-25)	33-39	33-39
Colour (5.25" Lovibond cell)	20 Red max.	3 or 6 Red max.

Source: Thiagarajan (1992)

Table 6 shows the good quality refined palm oil specification. When refined with proper refining procedures, the crude palm oils with the following quality is expected to produce good quality refined oils which can meet the specifications listed in Table 6 (Goh, 1993).

Free fatty acid	:	3% maximum
Moisture	:	0.1% maximum
Iron	:	3 ppm